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Abstract

DEVELOPMENTS IN NUCLEAR SUPERHEAT

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As is well known, the trend towards higher steam temperatures during the past half-century has resulted in an improvement in efficiency and decrease in power production costs in conventional turbine-driven electrical generating plants. By increasing the temperature of steam from boiling water reactors through nuclear means and utilizing the advanced technology in materials and equipment, it should be possible to likewise lower the cost of converting nuclear to electrical energy.

In order to investigate and solve the problems involved in superheating steam by nuclear means, the U. S. Atomic Energy Commission instituted an engineering and development program in 1958 in this matter. From the results of studies and the construction and operation of demonstration reactors, the most feasible and economic method of accomplishing this was expected to result.

It was anticipated that the feasibility and economics of superheating steam would depend on the problems encountered and methods selected to solve them. It was clear that certain factors might result in increased cost which, in turn, would have to be balanced against the advantages to be gained.

The problems which face the investigators in this program are discussed and the results of work which have been accomplished to solve them are presented in this paper. One of the anticipated problems is related to reactor safety and concerns the expected large change in reactivity in the event the normally voided superheated steam passages in the fuel elements are flooded with moderator water. The methods used to reduce the magnitude of the change or to reduce its rate are presented. Another factor with which the reactor designer must be concerned is that of the partition of power between the boiling and superheating regions of the integral reactor. Since burn-up of fuel and

fission product build-up are expected to change this division of power with time, methods of controlling and adjusting it must be incorporated and are discussed.

Since the desired steam temperature and reactor environment will result in fuel element cladding temperatures and conditions which present a materials performance problem, this matter is also considered and discussed.

In the normal operation of a boiling water reactor, reductions by factors as high as 10^4 in the content of radioactive contamination in the steam compared to that in the reactor water occur. This advantage is not expected to pertain in the superheater region when the outlet steam is compared to the inlet steam. Thus, any release of fission products or mass transfer of fuel cladding material would be expected to pass quantitatively to the energy conversion system and present operational and maintenance problems for such items as turbines, condensers, demineralizers, and their associated piping systems. This matter is duscussed in this paper, as is the development of water-steam separation devices at the superheater inlet.

Various studies of superheating reactor designs were undertaken in this program; and, from them, a number were selected for construction. These include designs which incorporate integral regions where steam generated in the boiling region is passed directly back through the superheating region in either the center or periphery of the core, as well as the design of a separate superheating reactor. Designation of them is given as EVESR, BONUS, BORAX V, and Pathfinder; and substantial operating experience with them will have been received by mid-summer 1964. Except for EVESR, these reactors are part of completely integrated electrical generating plants and, therefore, also serve to demonstrate the feasibility of operating such plants with superheated steam. Pertinent descriptions of each reactor, as well as the results of operational experience to date, are given in this paper.